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A Socio-Economic Evaluation of the SOx-charge in Japan*

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1. The pollution load levy and pollution reduction incentives

Pollution control policy for the reduction of sulfur oxides(SOx) emissions from stationary sources in Japan has been cited as a case of successful environmental policy worthy of international scrutiny (Weidner [1995]). A foundational component of this policy is the Compensation Law for Pollution-Related Health Damage, which was passed in September 1973 in order to provide redress for pollution victims, coming into effect in September of the following year. The Compensation Law imposed a system of pollution load levies (referred to hereafter simply as the CL levy) on stationary sources, and, although the system was not originally established as an economic incentive system to reduce emissions, this structure was akin to a system of emission charges in the sense that "taxes" were assessed on polluters. However, whether or not this system of levies provided an incentive effect leading to the actual reduction of pollution is the subject of debate.

Some investigators maintain that the CL levy system did not confer a pollution reduction effect. Horiuchi ([1995], pp.39-40), for example, shows that the average cost of SOx reduction at three thermal power plants exceeded the CL levy rate (fiscal 1979), suggesting that the installation of desulfurization equipment was due not to the Compensation Law but instead to direct controls. Tsukatani ([1983], p.20) also finds that the increase in production costs attributable to the CL levy was so small as to be hidden by price fluctuations, concluding that the levy had little inductive power, and that its pollution reduction effect was negligible.

Others assert that the CL levy did in fact deliver an incentive effect for pollution reduction. Imura ([1988], pp.115-8) compares the reduction rates of SOx emission between Compensation Law designated areas and other (non-designated) areas from the year that regulatory standards for total pollution load control were enforced (1978), finding that reduction rates were greater in those areas with relatively higher levy rates, and suggesting that differences in levy rates were a major factor. Weizsäker ([1994], p.126) holds that direct controls were rendered meaningless by the CL levy, stating that, "Japan also has emission standards for power stations, which, however, were rendered meaningless by the SO_2 charge.

It simply would not have occurred to a power station operator to exhaust the potential allowed by the standards, because of the expense."

The question arises, then, as to how such radically different evaluations can be produced. In fact, the aforementioned studies all contain methodological shortcomings that cannot be overlooked. The Horiuchi approach considers only desulfurization stack-scrubbers from among the various options for SOx reduction, while the greater portion of Tsukatani's "increase in production costs attributable to the CL levy" has no direct relation to the reduction of SOx emissions. A more appropriate comparison would be marginal abatement cost of SOx emissions versus the level of levy rates. Meanwhile, even if we ignore changes in industrial structure, Imura's comparison of SOx reduction rates from the year that regulatory standards for total pollution load control were enforced cannot be viewed as complete without empirical, quantitative consideration of the effects stemming from administrative guidance on the part of the national and various local governments and individually negotiated pollution control agreements. Furthermore, the study (Jesinghaus [1980]) which serves as the basis for Weizsäker's analysis neither appropriately compares levy amounts against SOx abatement costs nor recognizes the existence of pollution control agreements.

Given these sorts of limitations, it is difficult if not impossible to use existing research to definitively judge whether or not the CL levy provided a real incentive towards pollution reduction. Here, we will clarify the structure of the CL levy system from the standpoint of economics, and present empirical consideration of the effectiveness of the system in reducing pollution.

2. The framework of Japan's SOx reduction efforts

Since the early 1970s, SOx emissions have decreased nationwide. Reasons for this trend include the implementation of direct controls such as total pollutant load controls, higher prices for petroleum products caused by the two oil crises, and the CL levy (here we consider whether the CL levy actually deserves to be included in this list), which have resulted in a shift in Japan's industrial structure towards less energy-intensive, cleaner industries, the installation of desulfurization stack scrubbers, and the use of low-sulfur fuels.[1)] Accordingly, even in those areas of Japan most severely affected by air pollution, SOx concentration levels fell to within prescribed environmental quality standard(see Figure 1).

(insert here Figure 1)

Because it is generally held that the primary factor responsible for the accomplishment of these reductions was direct controls, let us first consider the basis for this view.

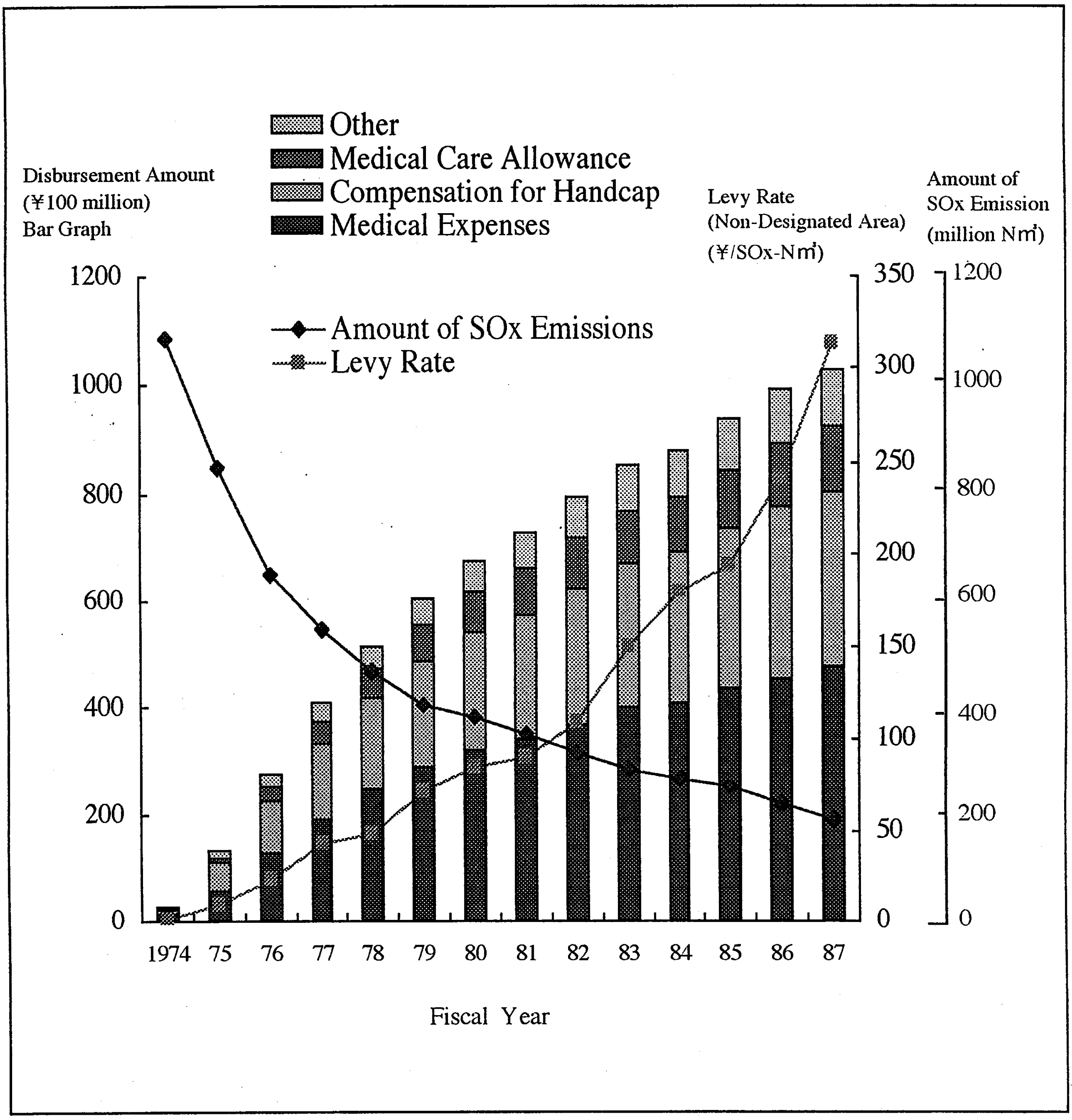
(1) National government-imposed legislative regulations

The 1962 Law Concerning Controls on the Emission of Smoke and Soot stipulated concentration standards for smokestack outlet emissions, but, because human health is affected by air pollution levels near the ground, K-value controls were implemented from 1968. The calculation of K-values is performed as follows:

$$q = K \times 10^{-3} \times He^2,$$

where q[Nm^3/h] represents tolerable limits of pollution per hour among facilities generating smoke and dust, and He[m] is effective chimney height. For each area, K-values were decided as part of overall policy, and amounts of SOx emissions were regulated for each individual stack. Gradually tightened revisions of K-values were carried out seven times through 1976. However, because it was difficult to meet environmental quality standards in concentrated industrial zones using K-values alone, total pollutant load controls were introduced in 1974 (although not completely enforced until 1978). By means of these regulations, the national government specified designated areas, with prefectural governments

Figure 1 SOx emission, Levy Rates and Disbursements



Note : The average levy rate in designated areas is simply mine times that in non-designated area, and the shape of the graph is analogous.

responsible for drawing up plans in order to meet environmental standards, giving consideration to local conditions, and establishing the following "a" and "b" values:

$$Q = a \times W^b,$$

where Q is the tolerable amount of SOx emissions [Nm^3/h], W is the amount of fuel used converted to heavy oil equivalent [kl/h], and $0.8 \leqq b < 1$.

Unlike K-values, which are calculated for individual stacks, regulatory standards for total pollutant load control are applied to entire plants, and are actuated for relatively large-scale installations (as defined by comparison of W values) that generate roughly 80% or more of total SOx emissions in a designated area. For smaller and medium-scale facilities, fuel usage regulations are employed which mandate the use of low-sulfur fuel. Further, for newly established emissions-generating installations, a stricter Q figure than in the foregoing formula is implemented. Despite being known as "total" pollutant load controls, however, permitted emissions are actually defined in terms of hourly flows, meaning that emissions foregone in one period or season cannot be "made up" in another. A total of 24 areas were officially designated from 1974 to 1976, with controls enforced in all of them by May 1978.

(2) local government-enacted ordinances and pollution control agreements

Local governments in Japan have generally preceded the national government in adopting pollution countermeasures. Local governments have often adopted more stringent emissions standards than the national government, leading the way by imposing their own total pollutant load controls. Additionally, local governments have negotiated pollution control agreements with large-scale facilities, and, even though these agreements are not legally compulsory and specify tighter limits than legislated standards, enterprises that have accepted such agreements have subsequently abided by them. Administrative guidance is also thought to have been useful in achieving SOx emissions reductions.

(3) Other Factors

Subsidies for the purchase of pollution control equipment were also made available, but these did not make a noticeable direct contribution to the reduction of SOx emissions. On the other hand, nationally administrated energy conservation policies and energy source diversification (i.e., away from oil) following the two oil crises, while not specifically designed to promote SOx reduction, are thought to have made a real contribution. And, through such legislation as the Industry Relocation Promotion Law, it is possible that contributions to SOx emissions reduction have been brought about in severely affected areas (for example, those areas designated by the Compensation Law for Pollution-Related Health Damage) by the consequent dispersion of polluting facilities to comparatively more rural sites.

3. The basic structure of the CL levy system

Apart from the above-mentioned control measures, and independent of the Air Pollution Control Law and other similar legislation, the Compensation Law imposed a levy on SOx emissions, naturally leading to assertions that it provided an incentive effect with regard to SOx reduction. Here, let us briefly consider the structure of the CL levy system.

(1) Overview of the CL framework

First, let us refer to the overall framework established by the Compensation Law as the CL framework. In addition, since all new certification of air pollution health victims was halted in 1988, the present research focuses primarily on the period prior to this extensive legislative revision.[2)]

The structure of the CL framework is illustrated in Figure 2; air pollution problems are relevant to Class 1 areas.[3)] The CL framework essentially provided for the collection of levies from SOx-emitting installations (accounting for 80% of CL-related disbursements) and a certain supplementary amount from motor vehicle taxes (furnishing the remaining 20% of disbursements), utilizing this pool of funds to compensate certified sufferers. In designating certified sufferers, the CL specified regions ("designated areas") where frequent occurrences of illness resulting from significant air pollution had occurred. When a person exposed to air pollution in the home or workplace beyond a specified period of time ("minimum exposure requirements") contracted chronic bronchitis, bronchial asthma, asthmatic bronchitis, pulmonary emphysema, or their sequelae ("designated diseases"), a causal relationship between such diseases and air pollution was systematically established. Compensation amounts were decided in advance, and the levies were collected in order to provide the funds necessitated by compensation payments. Here, we present the case of the levy system with regard to pollutants from stationary sources. Such levies were imposed on those facilities releasing maximum gas emissions over a certain threshold, and the number of installations from which levies were collected numbered between 8,000 and 9,000 annually.

(insert here Figure 2)

(2) Method of setting the levy rate

(a) Basic Structure

The levy rate is defined as amount of levy paid versus unit SOx emissions (yen/Nm^3). The conceptual formula for setting the levy rate is:

levy rate =

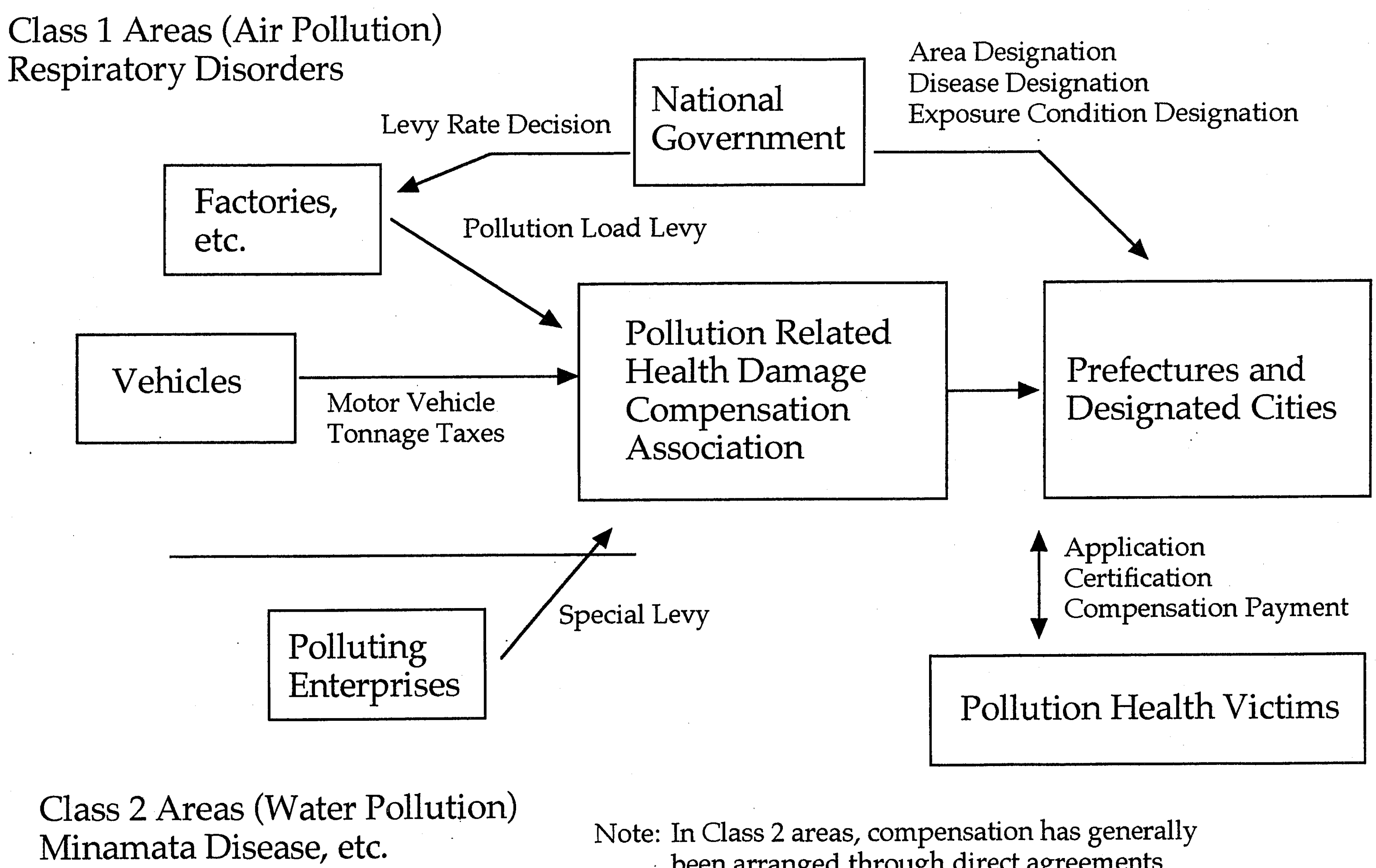
anticipated compensation disbursements in t fiscal year /

amount of nationwide SOx emissions in (t-1) calendar year

During (t-1) fiscal year, the Environment Agency projects anticipated disbursements in t fiscal year from past data, has major SOx emitters report their emissions records for the (t-1) calendar year, estimates total emissions accordingly, and set the levy rate by the end of (t-1) fiscal year.

The foremost feature of this framework is that the express purpose of the levy is to secure the level of funding dictated by compensation requirements, i.e., levy receipts are

Figure 2 CL Framework



Note: In Class 2 areas, compensation has generally been arranged through direct agreements between enterprises and victims or groups of victims.

decided first, followed by the levy rate. Next, SOx emitters do not know at the actual time of emission exactly what the rate will be. Third, levies are not imposed on emissions of nitrogen oxides(NOx) and other presumably health-deteriorative pollutants. Finally, because the health damage identified by the CL framework is stipulated to be cumulative and irreversible, even though health damage in t fiscal year is partly the result of emissions in (t-2) year and earlier, the entire burden of compensation disbursements is imposed on emitters in (t-1) year.

Viewed in light of the polluter pays principle, the third and fourth factors cited above place an unfair burden on current emitters of SOx. And, at the same time, the amount of compensation (i.e., levies) may well be virtually unresponsive to even major decreases in SOx emissions. This is accentuated by the fact that compensation is driven by total requests made by applicants, which, as the program becomes better known over time, is likely to expand. In other words, the amount of stipulated compensation is both independent of current SOx emissions, and, as suggested by the above-noted first feature of the framework, tends to induce expansion of the levy rate (see Figure 1).[4)]

The converse, however, is that excessive burdens placed on current emitters of SOx may serve as a deterrent to current SOx emissions. In general, if the amount of compensation for damage is averaged over polluting emissions, the levy rate becomes lower than the marginal damage cost caused by such emissions (the rate of a Pigouvian tax), thereby inviting a greater-than-optimal level of pollution (Hamada [1977], pp.93-101).But in case the damage is cumulative and irreversible and the pollution in the past was serious, where total compensation is covered by a levy on current emissions, the levy rate could exceed the Pigouvian tax rate. The fact that at almost 100per cent of observation points Sox concentration fell below the national ambient standard by 1980, 93.8% in1978FY, 98.9% in 1981FY, suggests that this is the case for the CL levy. That is, the resulting anti-pollution incentive would function even more strongly than a Pigouvian tax (see Figure 3). The foregoing line of reasoning is pursued from the standpoint of a Pigouvian tax which takes into account only the damage effected by current emissions in the current period of analysis, but even if a Pigouvian tax oriented toward future damage is considered, in the case of large past emissions, it is possible for the levy rate of a damage compensation system imposed only on current pollutant emissions to be higher than the Pigouvian tax.

(insert here Figure 3)

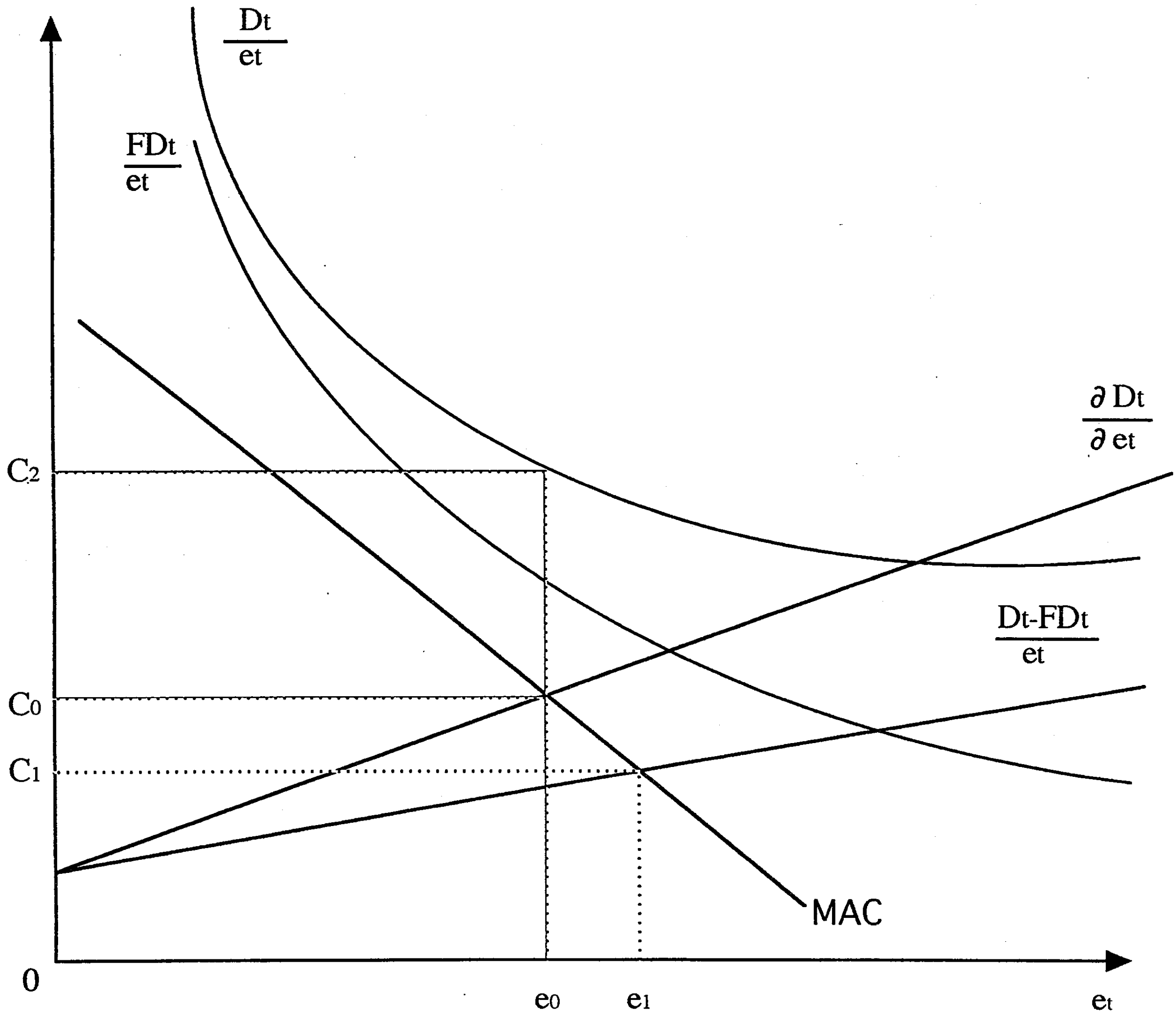
(b) Regional differences among levy rates

According to the principle that "liability for compensation" incorporated into regulatory reasoning (i.e., according to a report by the Central Environmental Pollution Control Council), it was contended that enterprises located in areas designated as having a high incidence of pollution-related health damage should pay at least half of total costs. Levy rates in designated areas were consequently averaged and set at nine times the rate in non-designated areas. However, because reduction rates of SOx emissions in designated areas were actually higher than in other areas, and because the "nine times" figure was not adjusted, the share of the total burden borne by enterprises in designated areas fell below 50% from fiscal 1979. When the law was subsequently revised, the share paid by enterprises in designated areas fell to about one third.

Differences in levy rates were established not only between designated and non-designated areas, but among designated areas as well. This was because, following implementation of the regulatory framework, sharp differentials appeared among designated areas in terms of the ratio between SOx emission levels and compensation amounts, and differing rates were required in order to rectify inter-area inequities.

As can be seen from the foregoing, levy rates were basically decided according to the need for funds, with adjustments made to allocate the burden between stationary and mobile sources of emissions and among various areas. It is theoretically possible for levy rates to be

Figure3 Damage Compensation Levy Rate versus Pigouvian Tax



e_t : amount of SOx emissions during period t
D_t : monetary amount of damage inflicted during period t
FD_t : monetary amount of damage inflicted during period t, caused by SOx emissions in the past and current/past other pollutions emissions, that is FDt=Dt (et=0). The value is exogenous to Figure3
MAC : marginal abatement cost of SOx emissions
e_0 : efficient amount of SOx emissions
C_0 : Pigouvian tax rate
C_1 : damage compensation levy rate in effect for damage inflicted during period t, that is Dt-FDt additionally caused by et.
C_2 : damage compensation levy rate in effect for Dt

Pigouvian tax rate C_0 attains efficient amount of SOx emissions e_0. When the damage is caused only by current SOx emissions, if the amount of compensation for damage is averaged over current SOx emissions, the damage compensation levy rate C_1 becomes lower than C_0 which entails more amount of SOx emissions e_1 than e_0. But if the damage is not caused only by current SOx emissions but also SOx emissions in the past and current/past other pollutant emissions, and if damage compensation levy was imposed only on current SOx emissions, the levy rate for emission level e_0, C_2, can become higher than C_0. In Figure 3, FD_t is assumed very large and Dt/et curve doesn't intersect and always comes over MAC curve. This means that the levy system always lacks in revenue to meet what is needed for compensation at any level of the levy rate. But the Japanese CL levy system actually imposes levy not on et but on e_{t-1}, which can't be changed during t period, so it cannot happen theoretically aside from the problem of disbursements projection and it hasn't happened empirically. Nontheless the shape of D_t/e_t curve suggests that if SOx emissions are reduced for any reason, the CL levy rate inevitably becomes higher.

higher than the corresponding Pigouvian tax, but whether or not the implemented levy rates provided an anti-pollution incentive to enterprises is an question that requires independent empirical analysis in order to resolve.

4. The pollution reduction effect of the CL levy

In determining if the CL levy system did in fact create an incentive effect, it is necessary to compare levy rates and marginal abatement costs of SOx emissions. Cost schedules according to each SOx reduction method are required in order to do so, but this kind of data is extremely difficult to obtain. Thus, as a practical measure, we have limited our consideration to thermal power plants in Osaka Prefecture, one of the most densely populated areas of Japan.

(1) A case atudy of thermal power plants in Osaka prefecture

(a) Reasoning supporting case selection

Viewed by industry, electric power generation is the largest producer of SOx, accounting for over 30% of emissions. Even within designated areas, where the steel industry is the leading emitter, electric power ranks second with about 20% of emissions. Thus, consideration of reductions in SOx emissions achieved by the electric power industry provides a reasonable picture of the overall situation. Also, given the nature of the participating enterprises as public utilities, and specifically because the Osaka Prefectural Government and Kansai Electric Power Corp. (the regional electric utility) have concluded a pollution control agreement, required data on estimated costs is more readily available than for other industries and areas, thereby allowing more detailed analysis.

(b) The Relationship between Pollution Control Agreements and Total Pollutant Load Controls

The pollution control agreement between Osaka Prefecture and Kansai Electric Power was concluded in May 1974, and it originally specified annual SOx, annual NOx, and daily SOx emissions limitations, as well as sulfur content of fuel, amount of fuel used, and the utilization rate of generating plants. The thermal efficiency of the power plants did not change to a significant degree, but, because the agreement did take efficiency into account, limitations on fuel use and plant utilization rates served as a proxy from the standpoint of emissions. Additionally, since maximum permitted SOx emission is the product of maximum permitted fuel use and maximum permitted sulfur content, the specified emissions targets are automatically achieved so long as fuel use and sulfur content limits are carefully adhered to. The agreement was modified in March 1980, eliminating fuel use (and, practically speaking, utilization rate) limits for plants equipped with denitration stack scrubbers. However, other control values specified by the agreement, even at their weakest in fiscal 1975 (the first year of implementation), were stricter than subsequently adopted total pollutant load controls, and were actually tightened over time.

(c) The SOx Emissions Reduction Record at Thermal Plants in Osaka Prefecture

Kansai Electric Power consistently adhered to the agreement, and has since reduced its SOx emissions. Such reductions are generally considered to be achieved at thermal power plants by reducing the amount of electricity generated, improving thermal efficiency (i.e., energy savings), using low-sulfur content fuel, and/or installing desulfurization stack scrubbers. Total power generated by Kansai Electric increased over the period of consideration, but most of the increase can be attributed to nuclear power plants. Although nuclear plants raise issues apart from air pollution, it cannot be denied that their use holds down increases in SOx emissions. However, the decision to move towards nuclear power generation is preferentially influenced by energy policy independent of strategies for air pollution reduction. For the purposes of simplification, therefore, SOx reduction measures are considered by taking the volume of electricity generated at each thermal plant as given.[5] The period of analysis is for the years after 1975, for which data is available.

Of the above-noted SOx-cutting methods, energy savings at individual existing plants (improvement of thermal efficiency) is technically difficult, leaving low sulfur-content fuel and desulfurization stack scrubbers as realistic options. Let us then weigh the respective costs of SOx reduction for these two methods. Figure 4 shows the relationship between SOx emissions and cost (converted to cost per kl of heavy oil) faced in fiscal 1975 by the area's largest thermal generating plant, Sakaikou Power Station.[6] It can readily be seen that SOx reductions bring about increased costs, and, as a profit-motivated enterprise, Kansai Electric could be expected to implement the least expensive method of reaching targeted emissions levels. According to Figure 4, if desulfurization stack scrubbers are not installed, C heavy oil only can be used for a level of SOx between 10.8 and 18.9 [Nm^3/kl], a mixture of C heavy oil and crude oil for between 0.63 and 10.08 [Nm^3/kl], and a mixture of LNG and crude oil for between 0 and 0.63 [Nm^3/kl]. When the option of desulfurization stack scrubbers is considered, C heavy oil alone (without scrubbers) can be used to achieve emissions of between 12.6 and 18.9 [Nm^3/kl], C heavy oil with partial installation of scrubbers for 1.89 to 12.6 [Nm3/kl], and low-sulfur fuel with full installation of scrubbers for 0.63 to 1.89 [Nm^3/kl]. The pollution control agreement called for sulfur (S) content of 0.16wt% (1.0 [Nm^3/kl]), and an annual average level of 0.15wt% (0.95 [Nm^3/kl], or total annual SOx emissions of 5,440t) was in fact achieved.[7] From the figure, it can be seen that a combination of crude oil, heavy oil, and volatile oil (such as naptha and natural gas liquids -- not LNG) in the ratio of 97 :3: 0 (heat generation comparison) would be the least cost alternative, and this is roughly matched by the actual ratio of 77: 17: 7 (rounded) that was adopted. Desulfurization stack scrubbers would have been a viable choice given these levels of emissions, but it appears the decision had already been taken at this point to convert to LNG, thus obviating the future need for scrubbers.

Constructing a marginal abatement cost curve according to Figure 4, we arrive at Figure 5; the level of SOx emissions determined by the CL levy rate (the following year's rate versus relevant emissions) was 15 [Nm^3/kl], as opposed to the achievement of actual emissions of 0.95 [Nm^3/kl] between r_2 and r_4 in Figure 5, showing that the CL levy played no role at all in the reduction of SOx emissions.[8] Accordingly, the reductions must be attributed to the pollution control agreement. Given certain periods of full plant utilization, the maximum daily emissions level (ten day average) set by the agreement is more stringent than the annual level, and the achieved level of 21.1 [t/day] (or 0.63 [Nm^3/kl]) was under the agreement level of 22.6 [t/day] (or 0.67 [Nm^3/kl]).

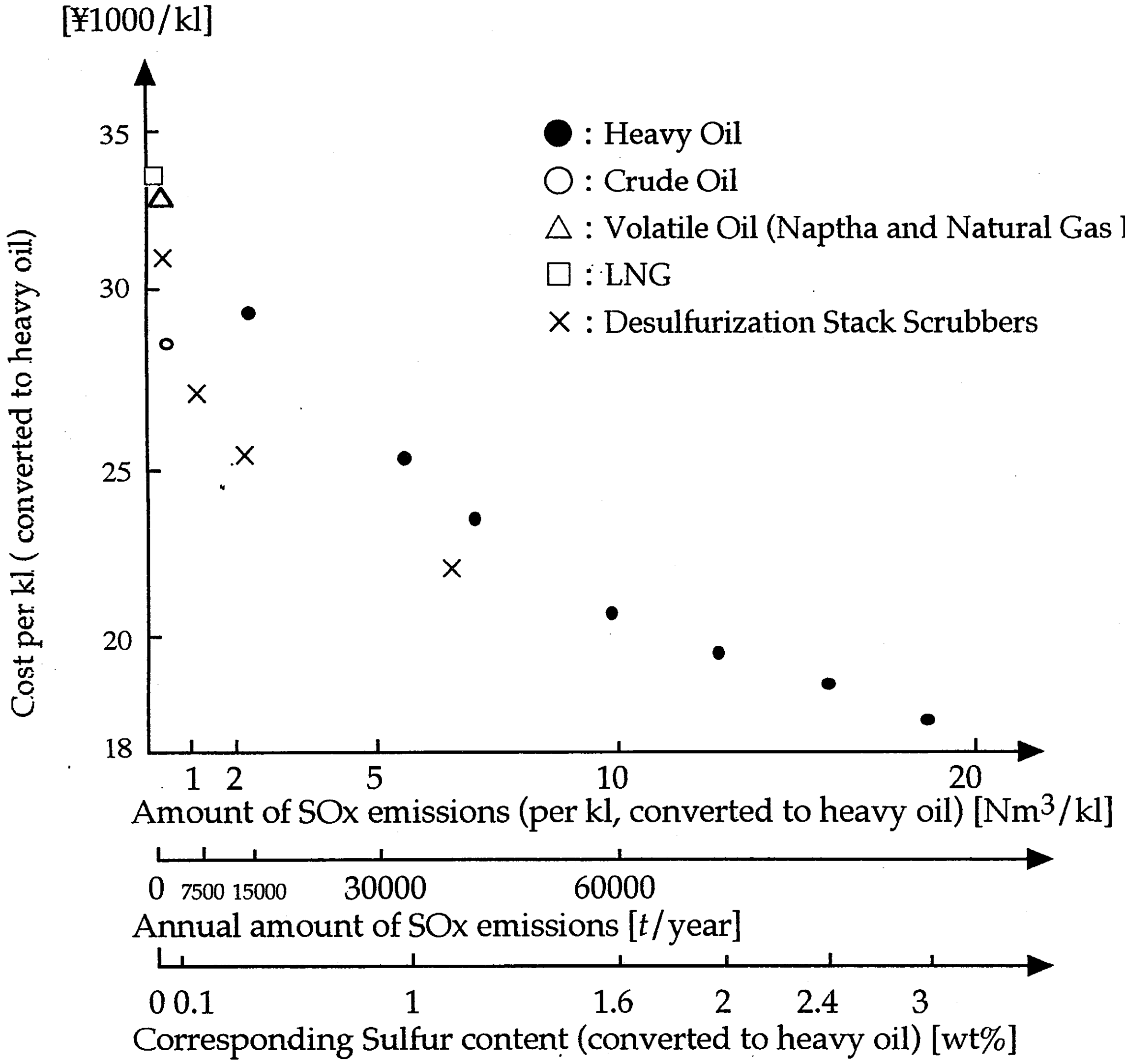
(insert here Figure 4, Figure 5)

CL levy rates subsequently rose, but the analysis for the same (Sakaikou) installation yields the same result in 1980, with Figure 6 illustrating the relationship between the amount of SOx emissions and costs. As can be gleaned from the figure, the price of virtually non-sulfur LNG is below that of other fuels.[9] The use of LNG alone allows cost minimization, and also leads to minimization of SOx emissions (this state of affairs has continued up to the present). In this case, neither total pollutant load controls nor the pollution control agreement have any bearing on the reduction of SOx emissions. In fact, however, a mix of about 70% LNG with the remainder made up of crude and heavy oil was used; because of the nature of long-term LNG contracts, there are limits on the amount that can be used. Without such limits, similar curves could be constructed for other plants, all of which would be using 100% LNG. But this is not the case, as dictated by energy source diversification policy and difficulties in locating LNG storage facilities.

(insert here Figure 6)

Hence, let us examine the case of oil-fired thermal plants which are both located in the same designated area and which do not use LNG. None of the three such plants found use crude oil, which contains relatively little sulfur and is comparatively inexpensive. Instead all three exclusively rely on heavy oil, meaning that the marginal abatement costs of SOx emissions are high and that the CL levy should not have had any effect as of 1980.

Figure 4 SOx Emissions and Costs at Sakaikou Power Station (FY1975)

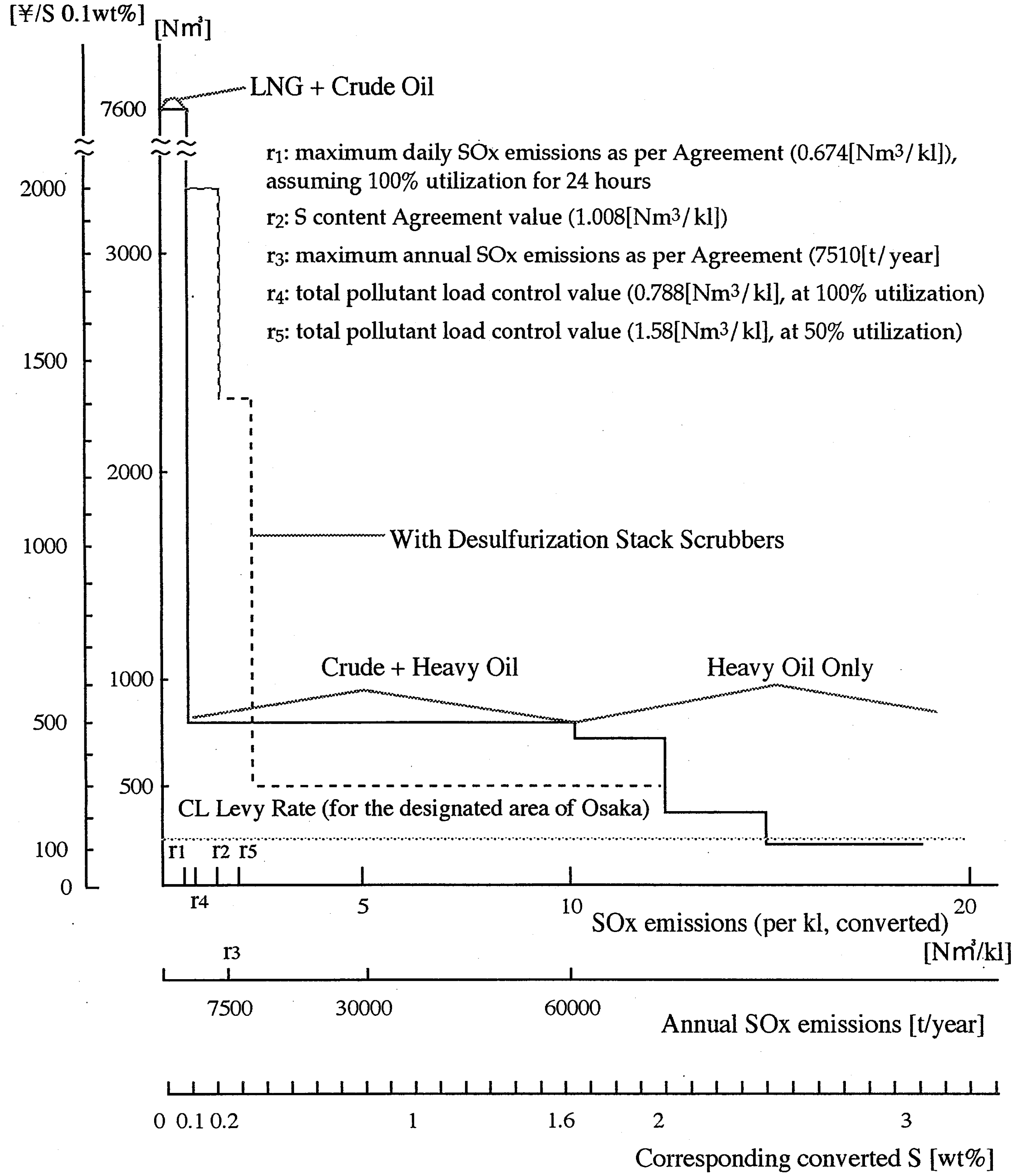


Notes: 1) Heavy oil is for Jul.-Sep. 1975 (Nippon Oil, prices for electric power companies), taken from the 1984 edition of *Oil Price Statistics*.

2) Crude oil, volatile oil, and LNG represent the average FY75 purchase price paid by Kansai Electric Power, taken from the 1980 edition of *The Current State of KEP*.

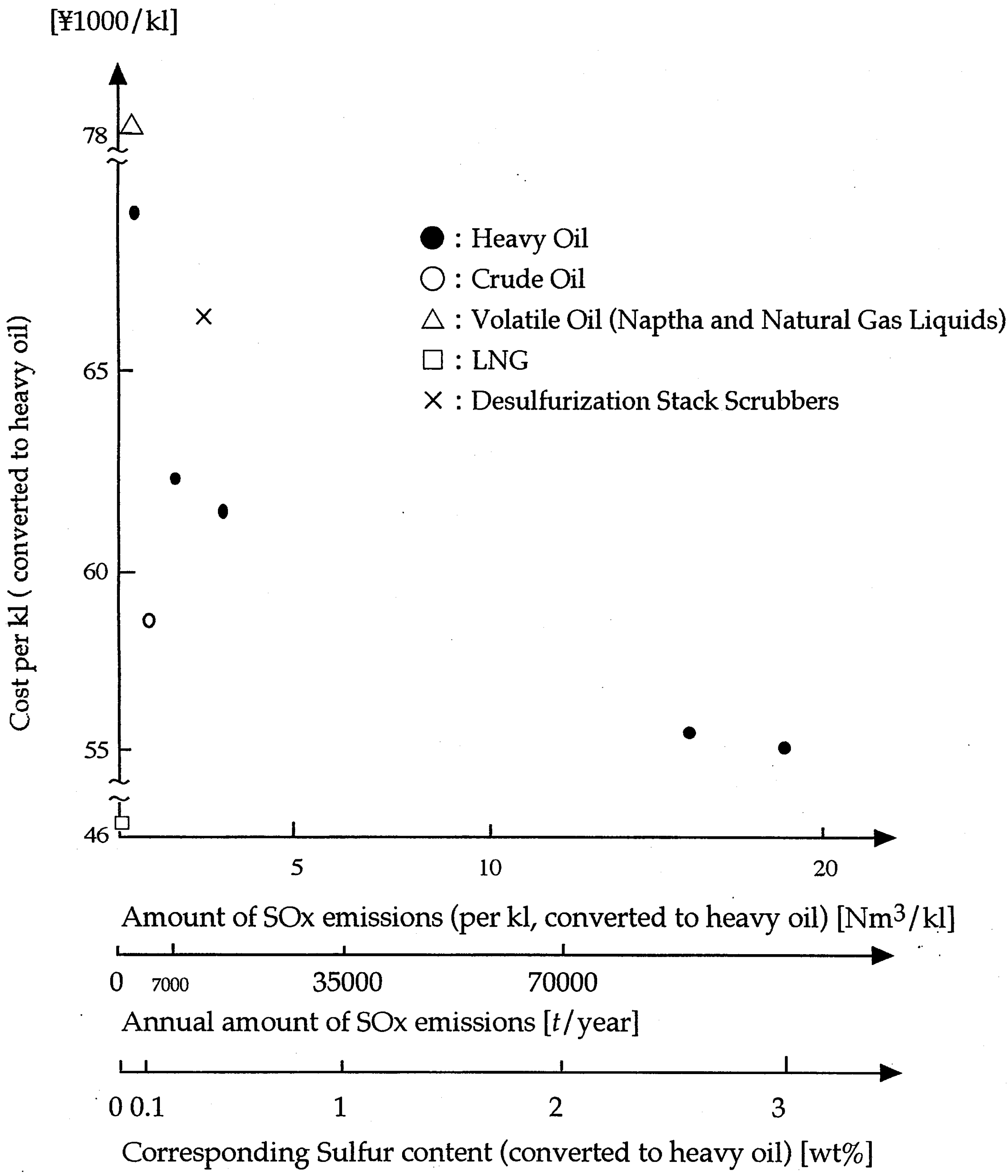
3) Efficiency of 90% is assumed for desulfurization stack scrubbers. Cost Schedule of desulfurization stack scrubbers was estimated based on *FY85 Report on Smoke and Soot Control Technology* prepared by the Japan Industrial Equipment Association.

Figure 5 SOx Marginal Abatement Cost at Sakaikou Power Station (FY1975)



Note: Total pollutant load control values for r4 and r5 were not yet in force.The FY1975 utilization rate was 48.7%.

Figure 6 SOx Emissions and Costs at Sakaikou Power Station (FY1980)



Notes: 1) Heavy oil is for Jul.-Sep. 1980 (Nippon Oil, power generation basis), taken from the 1984 edition of *Oil Price Statistics.*

2) Crude oil, volatile oil, and LNG represent the average FY80 purchase price paid by Kansai Electric Power, taken from the 1985 edition of*The Current State of KEP*

3) Same assumption for desulfurization stack scrubbers as in Fig. 4.

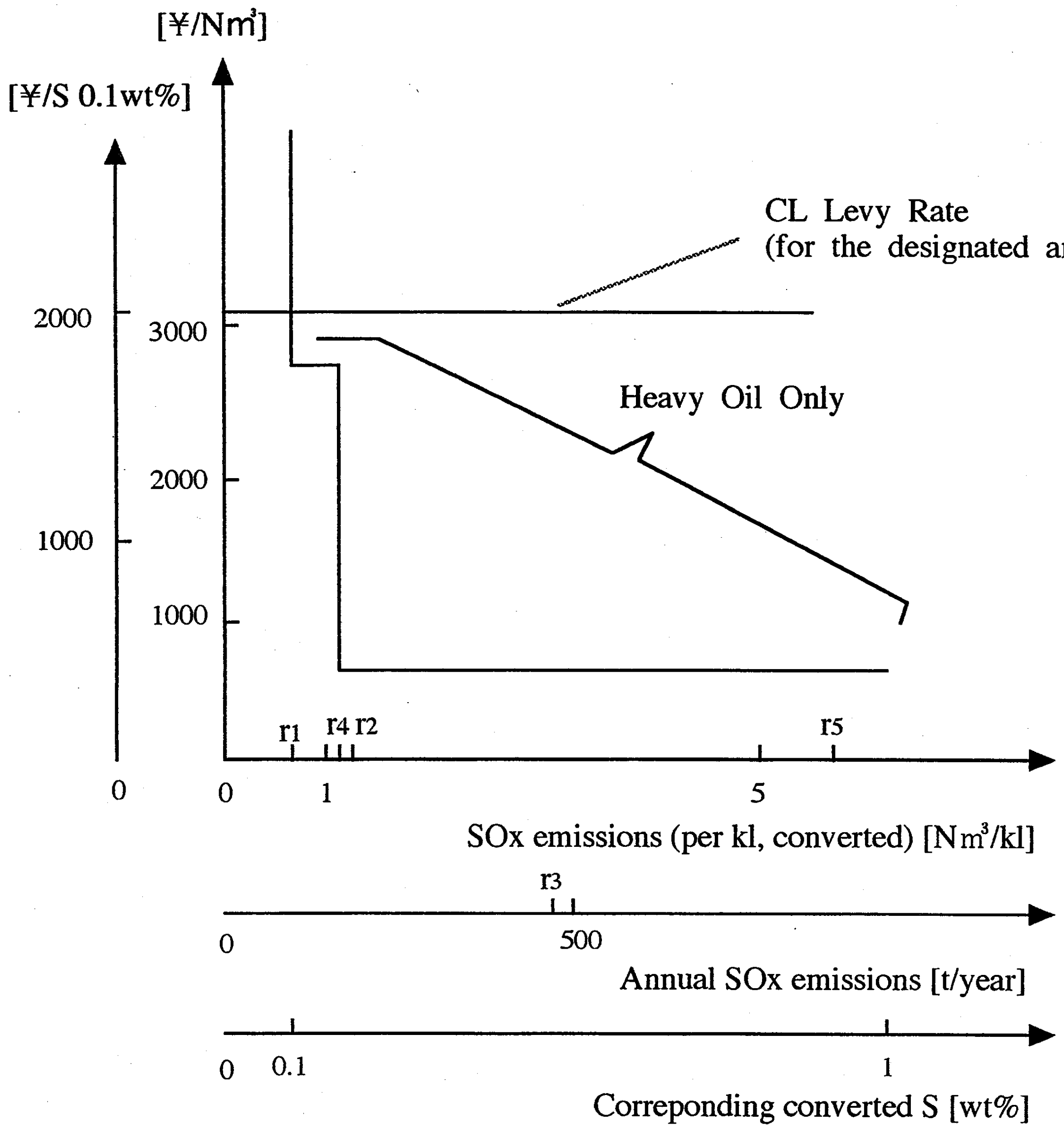
Conditions changed in 1983, however, such that price differentials shrank among heavy oils with differing sulfur content. Figure 7 represents the marginal abatement cost curve for one of these plants, known as the Sanpou Generating Station. The annual average sulfur content of fuel was specified in the pollution control agreement as 0.2wt% (1.3 [Nm^3/kl]), while a level of 0.12wt% (0.76 [Nm^3/kl], or SOx emissions of 110t/year) was actually achieved between r_1 and 1 in Figure 7. There is a possibility, then, that the CL levy did provide a reduction incentive effect, although one reason for this is that the plant is small-scale (only 8% of the generating capacity of Sakakou) and is subject to looser standards with regard to the pollution control agreement and total pollutant load controls.

(insert here Figure 7)

Meanwhile, a plant located in a more rural part of the prefecture where regulatory standards on total pollutant load control are loose, control agreement values are strict, and, because the area is non-designated for Compensation Law purposes, where the CL levy rate is low, there is no indication that the CL levy provided any pollution reduction effect. In the end, consideration of individual power generating plants suggests that SOx reductions at thermal plants in Osaka Prefecture were essentially due to the pollution control agreement and to relative declines in the price of LNG. Basically, the CL levy was not responsible for a significant pollution reduction effect, although there is a possibility that the levy did come into play due to the narrowing of price gaps among fuels with differing sulfur content, in a case where both total pollutant load control and the effected pollution control agreement had weak influence because the scale of the plant in question was small.

(b) Effects on small and medium enterprises

Figure 7 SOx Marginal Abatement Cost at Sanpou Power Station (FY1983)



r_1: maximum daily SOx emissions as per Agreement (0.63[Nm^3/kl]), assuming 100% utilization for 24 hours

r_2: S content Agreement value (1.26[Nm^3/kl])

r_3: maximum annual SOx emissions as per Agreement (470[t/year]

r_4: total pollutant load control value (1.17[Nm^3/kl], at 100% utilization)

r_5: total pollutant load control value (5.83[Nm^3/kl], at 20% utilization)

Note: The FY83 utilization rate at the Sanpo Power Station was 15.1%.
The price of C heavy oil for power generation is for Apr.-Dec. 1983, taken from the 1989 edition of *Oil Price Statistics*.

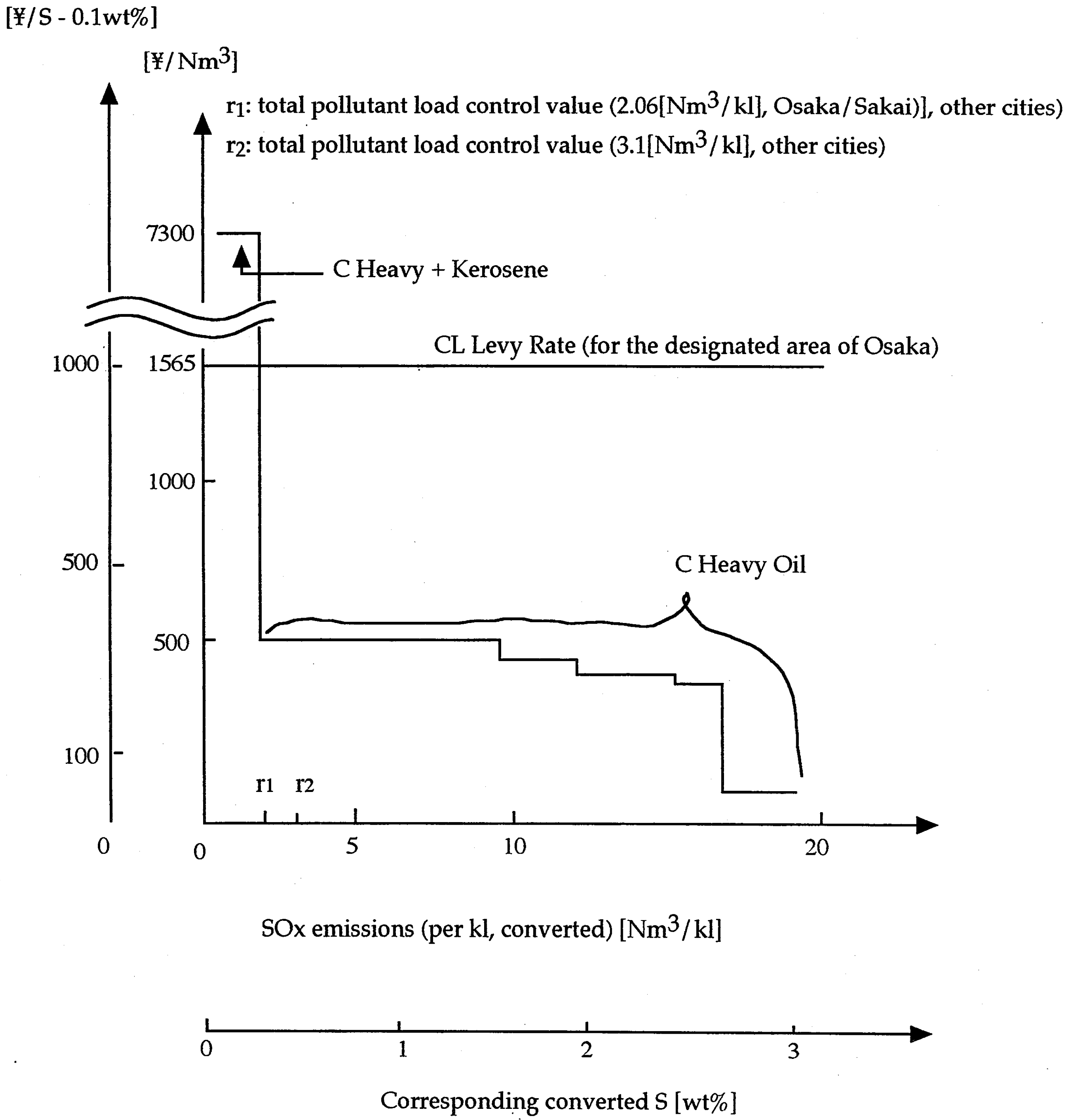
Assuming the same features resulting from the formula deciding CL levy rates as noted in part (2) of section 3, and given that large-scale producers reduced their SOx emissions, there is a possibility that the CL levy did generate a pollution reduction incentive among small and medium enterprises located in the same areas as large-scale emitters, and therefore subject to the same levy rates, but facing relatively less stringent direct controls.

Before concluding, then, let us consider a case in the vicinity of Osaka City. The minimum scale for application of regulatory standards for total pollutant load control in this area is defined as a rated fuel consumption of 0.8 [kl/h] (or about 2% of that of the Sanpo Power Station), equivalent to an approximate gas emissions level of 9,400 [Nm^3/h]. This level is well above the 5,000 [Nm^3/h] maximum gas emissions threshold for required payment of the CL levy, and is therefore within the range of consideration of the CL levy rate incentive effect. Minimum scale for application of the regulatory standards for total pollutant load control is 1.65 [Nm3/h] (or 2.06 [Nm^3/kl]) for Osaka City and Sakai City, and 2.48 [Nm^3/h] (or 3.1 [Nm^3/kl]) for other municipalities in the prefecture. Desulfurization stack scrubbers are comparatively expensive for operations on this scale, and the main anti-SOx measure consists of fuel choice (C heavy oil, A heavy oil, or kerosene). Constructing a SOx abatement cost curve as with large-scale power plants (see Figure 8), it appears that the levy did not play a role in 1975, but that a SOx emissions reduction incentive was manifested in 1980 as a result of narrowed price gaps among fuels with differing sulfur content and of higher levy rates. The situation appears to be the same after 1980 as well.

(insert here Figure 8)

5. Conclusion

Figure 8 SOx Marginal Abatement Cost for Small/Medium Enterprises (FY1980)



For electric power generating plants in Osaka Prefecture, the main factor inducing reductions in SOx emissions was not the CL levy but direct controls, especially those controls stemming from the pollution control agreement concluded with the regional electric utility. However, the anti-pollution incentive effect of the CL levy cannot be completely ignored, as it does appear to have come into play in a limited sense. The effect is found to strengthen over time vis a vis small and medium scale power plants and manufacturing enterprises which are subject to relatively weaker direct controls, under conditions where there are ongoing narrow price gaps among differing sulfur content fuels and rising levy rates.

CL designated areas in Osaka Prefecture feature the highest levy rates in Japan, but, because direct controls such as total pollutant load controls and pollution control agreements are also quite strict, there is not much scope for the operation of CL levy-induced pollution reduction incentives. However, even in areas where levy rates are somewhat low, but where direct controls are also relatively weak, an anti-pollution effect rather greater than that seen in the Osaka region may be expected.

Notes

1) Other causative factors in SOx reduction include government assistance programs for pollution prevention investment such as policy-tied financing, special depreciation, accelerated depreciation, but, in the case of the steel industry for example, the effect of subsidy policies is deemed to have been slight. See Matsuno [1997a,b].

2) Here we consider only the functions of the CL levy system. An outline of the establishment of and influences on the system will be made the subject of a future paper, but refer to Matsuno [1996].

3) The Compensation Law stipulates Class 1 (air pollution) and Class 2 (water pollution) areas. Here, we limit discussion to the levy system for the former. Fore more on the composition of the system, see Kido [1975].

4) A straightforward comparison of similar sorts of systems in other countries is complicated by differing purposes behind the systems and differing country conditions. For reference, however, if tax (or similar instrument) rates on SOx emissions and sulfur content in fuel are comparatively aligned with CL levy rates (unitized as [¥/SO_2-kg]), Sweden has a sulfur tax rate of 339 (1991), Norway has a sulfur tax rate of 299 (1988), France has an air pollutant emissions surcharge rate of 3-4 (1985-90), and the US has an average SO_2 emissions permit price of 17(1994), 12(1995). Meanwhile, Japan has rates of 741-1877 (for designated areas, as of 1987) and 110 (for non-designated areas, 1987); levy rates in CL-designated areas can be seen to be quite high compared to charges in other countries. Figures for Sweden, Norway and France are from Ishi [1993]; for the US, from *The New York Times* March 23, 1996, p.35; and for Japan from the Environment Agency [1994]. Yen exchange rate conversion is according to arbitrated and standard rates of exchange in The Bank of Japan [1996] *Economic Statistics Annual 1995 Edition.*

5) There is of course the issue of the allotment of power generation among power stations, but we assume this issue was decided upon without particular regard for anti-SOx measures, given thermal efficiency of each power station and the prices of fuel consumed there.

6) Here, cost is the sum of the cost of fuel and the cost of desulfurization (when desulfurization stack scrubbers are installed). Cost in cases where low-sulfur fuel is used is represented for various fuel types (according to sulfur content) converted to price per kl of heavy oil. With regard to reductions in emissions of SOx by means of desulfurization, cost was calculated based on the sequential introduction of desulfurization stack scrubbers at the eight generation units of Sakaikou Power Station, together with changeover to low-sulfur fuel. It was thereby found that the least-cost method of reaching specified emissions targets was as follows. Desulfurization stack scrubbers were needed when Sox emissions of under 12.6[Nm^3/kl] were required. Desulfurization stack scrubbers are introduced for each unit seaquentially, equipped units using 3wt% C heavy oil and non-equipped units using 2wt% C heavy oil. After all units had been fitted with scrubbers, lower-sulfur than 3wt% C heavy oil fuel is introduced for

equipped scrubbers. This was found to be the most cost-effective procedure. In Figure 4 (number of units with desulfurization stack scrubbers, heavy oil conversion sulfur content of fuel, fuel used for equipped unit) from the right, (4/8 units, 3wt%, C heavy oil), (8/8units, 3wt%, C heavy oil), (8/8units, 2wt%, C heavy oil), and (8/8units, 1wt%, combination of C heavy oil and crude oil) are represented by the four X points.

7) As the power plant utilization rate (i.e., the amount of fuel used) is fixed, annual SOx emissions and average S content are synonymous.

8) When a line joins the points representing the least-cost means of achieving the values for SOx emissions in Figure 4, absolute values for the slopes of the line segments is the vertical axis SOx marginal abatement cost shown in Figure 5. However, within the dotted line labeled "With Desulfurization Stack Scrubbers" in Figure 5, the section from 1.89-12.6 [Nm3/kl] is not realized continuously, and only seven points (making the eight segments) can be established. Although emitters can't tell the following year's rate, as the rate is higher than that of previous year, conclution which reject the effectiveness of the levy is reinforced.

9) This sudden fall of LNG price is mainly due to the introduction of Indonesian LNG in 1977 based on the long-term contract between KEP and a Indonesian public corporation and it doesn't mean this radical fall of international price for LNG.

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